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POST-CONSUMER PLASTIC RECYCLING - THE RESOURCE PLASTICS INC. EXPERIENCE

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Post-consumer plastic recycling :
the Resource Plastics Inc.
experience / Horn, James T.

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POST-CONSUMER PLASTIC RECYCLING - THE RESOURCE PLASTICS INC. EXPERIENCE

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This report was prepared for the Ontario Ministry of Environment and Energy (formerly Ministry of the Environment) as part of a Ministry funded project. The views and ideas expressed in this report are those of the author and do not necessarily reflect the views and policies of the Ministry of Environment and Energy, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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Post-Consumer Plastic Recycling
The Resource Plastics Inc. Experience

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Executive Summary

Post-Consumer Plastic Recycling
The Resource Plastics Inc. Experience

Resource Plastics Inc. (formerly "Corp.") was the product of a technical and economic feasibility study conducted by the writers' in the fall and winter of 1988-89. This study, partly funded by the Ministry of Environment and Energy ("MOEE") under the Industrial Waste Diversion Program ("IWDP") had as its goal the provision of adequate knowledge upon which an informed assessment with respect to the viability of investment in and operation of a post-consumer plastic recycling facility in Ontario could be made. Our study determined that the key factors for success were that:

1) sufficient sources of recyclable post-consumer plastic materials needed to exist, e.g. household bottles;
2) an adequate collection mechanism was required, e.g. Bluebox curbside collections;
3) significant deficiencies in post-consumer plastic recycling technologies had to be overcome;
4) markets for recycled plastics were immature, undefined and would need considerable effort to gain a toehold;
5) long-term economic viability rested upon development of higher-value end products; and,
6) a high level of polymer knowledge and skills, coupled with substantial financial backing and capabilities were essential.

Completed in March 1989, the study nonetheless concluded that real opportunities existed for a properly focussed plastic recycling operation to survive and eventually prosper. Shortly thereafter, private investors were found, term and operating bank loans were arranged and a new company called Resource Plastics started buying equipment in June 1989. Resource's initial focus was on selected post-industrial and post-consumer curbside plastics, processing the two main commodity polyolefin resins, polyethylene ("PE") and polypropylene ("PP"). At this time, an initial capital and process commissioning grant was obtained from the MOEE (referred to as the"Phase 1 grant").

As we begun processing materials in the spring of 1990, numerous collection, technical and marketing challenges became evident. While supplies were generally plentiful, quality of the recyclables was a serious problem with respect to non-plastic and incompatible plastic contamination. The recycling technologies that we had purchased could deal with certain problems or degrees of a problem, but not nearly all the processing challenges that appeared.

Market development and acceptance was a protracted affair. Materials were acquired for recycling in anticipation of sales that looked promising but never materialized. As well, in the absence of mandating or coercive pressure, brand users did not move to introduce post-consumer resin ("PCR") in their product packaging.

We were losing lots of money very quickly. The shareholders injected more money to keep Resource going. Our equity investment was now $3.5 million.

In the early winter of 1991, we started to get a few breaks. A number of equipment bugs were corrected. Dow Chemical Canada Inc. approached us proposing a fairly substantial supply-marketing arrangement selling PCR from high density polyethylene bottles. As part of that agreement, concluded in March 1991, Dow assisted Resource to help purchase and install some $2.5 million of retrofits and new process equipment required based upon our experience. The MOEE also assisted in this significant process enhancement with a second grant (referred to as the "Phase 2, Stage 1" grant).

The retrofit was done in July 1991. In August we financially broke even for the first time and became profitable in the succeeding months. Our core business became recycling HDPE bottles from curbside collection operations, most notably Ontario's "Bluebox" system. The supply agreement with Dow allowed us to focus on the recycle manufacturing challenges while Dow focussed on distribution, technical support and marketing. It has been a very beneficial relationship for Resource.

In the fall of 1991, we also started to more effectively recycle PE film, mainly from grocery store used bag collections. We also began experimenting with stretch film recycling. These development activities led in 1992 to a multi-year supply agreement with Rubbermaid Commercial Products Inc. and a $6 million film recycling venture. In this regard, we received a further grant from the MOEE IWDP ("Phase 2, Stage 2"). These activities will form the basis of a separate report, as this report concentrates on Phase 1 and Phase 2, Stage 1 grant activities only.

ACKNOWLEDGEMENTS

Resource is emerging as a leading North American recycler of post-consumer HDPE bottles and PE film materials. Resource is deeply grateful to the MOEE as well as Dow Chemical for the financial support and encouragement they have consistently provided. In addition, the company wishes to commend The Government of Canada's Scientific Research and Experimental Development Investment Tax Credit program which has also contributed greatly to help fund Resource Plastics' technology development activities.

REPORT

This report has been prepared to fulfill grant requirements of the MOEE Industrial Waste Diversion Program.

Post-Consumer Plastic Recycling
The Resource Plastics Inc. Experience

Introduction

Plastic waste can be divided into basically four categories, each category representing significant quantities of waste produced daily:

1) dry, clean, single resin materials, typically post-industrial scrap, e.g. trim scrap from bottle or bag-making operations;
2) dry, clean, multi-resin or laminate materials, typically post-industrial scrap, e.g. disposable diaper leg cut-outs;
3) dirty, wet, single resin materials, typically selected post-industrial or post-consumer waste, e.g. agricultural film, pallet stretch film; and,
4) dirty, wet, co-mingled resin materials, typically post-consumer waste, e.g. curbside rigid bottles.

The first category of waste has long been recovered by plastics manufacturers. This material is often referred to as "regrind". The second category of waste has rarely been recovered by manufacturers, typically due to processing/application difficulties arising from the multi-material nature of the waste. Likewise, the third category of waste has rarely been recovered, due to the requirement to remove the surface contamination and dry the plastic before re-extruding. The fourth category had not been recovered at all, due to absence of collection mechanisms, recycling technology deficiencies and end-product markets.

Resource Plastics' recycling objectives stated from the outset have focussed on wastes generated under categories 2 to 4. These categories represented untapped sources of potentially high-value plastics once recycled. In Phase 1 of our program with the MOEE, we discovered by experience that we had acquired technology that could handle a number of wastes in category 2 and 3, but could not handle category 4 wastes at all. The Phase 2, Stage 1 retrofit was directed at adding technology and processes that would permit handling a broader range of category 4 wastes.

The purpose of this report is to review each of Phase 1 and then Phase 2, Stage 1 project activities from the standpoint of the key success factors outlined above; that is:

1) sourcing of recyclable plastic waste materials;
2) collection mechanisms, e.g. Bluebox curbside collections;
3) determining and remedying deficiencies in post-consumer plastic recycling technologies acquired;

4) market development activities;
5) development of higher-value end products; and,
6) acquisition of skilled personnel and discussion of financial resources required.

Phase 1 Project Activities

Equipment Selection

Resource ordered a plastics wash recycling line in the summer of 1989 from Herbold Germany for delivery in January 1990. This line's unit operations then consisted of:

a) a guillotine cutter, which received bales of material cutting material into slices. Undesired material was out-sorted in a small section conveyor before entering;
b) a shredder, whose counter-rotating lobes shredded plastic into hand-sized pieces;
c) a large inclined conveyor elevated material to;
d) a float-sink tank, where heavy materials such as stones, glass, metal and some plastics were sunk out; floating material was paddled over a wier to;
e) a wet granulator, where material was concurrently size-reduced and cleaned in a wet rotary cutting chamber; half-inch material then passed through a sizing screen to;
f) two friction washers, which quickly augered material upwards at a 45 degree angle against a countercurrent water stream; pulped paper labels and other grit is flung through mesh that wraps these augers;
g) material was then mechanically and thermally dried;
h) material, in flake form, was then remelted, filtered and repelletized in an extruder operation. The material was then boxed and ready for sale.

Resource acquired extrusion equipment in the late fall of 1989 that permitted us to recycle both rigid and film flake material. This extruder, manufactured by EREMA Austria, also has a sophisticated melt filtration unit, permitting futher cleaning of the plastic while in molten form.

The wash plant equipment was installed commencing in February 1990. The line was started up in April. Many startup problems arose. We had electrical and mechanical problems due to incorrect drawings and inadequate field support from Herbold. Automatic cycling routines in key units failed. Pumps were sized incorrectly and had to be replaced.

We experimented with numerous water filtration mechanisms, as until we ran materials we had very little understanding of what the requirements would be. We encountered many failures and reworked plumbing many times. The filtration devices ultimately selected must balance the effluent requirements of the municipality, end-product quality needs which are affected by unfiltered solids in the water, as well as operating and capital costs associated

with the various solutions available. A fuller discussion of the wash equipment's capabilities is included below.

Sourcing of Recyclable Plastic Waste Materials

As the EREMA extrusion line was the first equipment installed and operating, our early Phase 1 emphasis was on procuring and test recycling of category 2 waste materials. We tested our equipment's capabilities on over 50 varieties of dry, multi-material wastes. Some principal examples included:

1) diaper leg cutouts, a laminate of PP and PE film;
2) PP snack food packaging scrap, e.g. chip bags;
3) PE snack food packaging scrap, e.g. Tetra-Pak liners;
4) vacuum-metalized PP food packaging scrap, e.g. Hostess chip bags;
5) foamed PE pool cover insulation;
6) paper/PE food packaging, e.g. Tang orange drink packaging scrap;
7) acrylic-coated PP pasta wrappers;
8) carpet scrap;
9) woven PP tote bags;
10) PE/nylon food package laminates;
11) acrylic-coated PE food wrappers; and,
12) silicone-coated PP film, e.g. pressure label back-sheets.

With the startup of the wash plant in April 1990, we turned our attention to streams of category 3 and 4 materials for testing. Some of the category 3 materials we tested were:

1) PE agricultural mulch film;
2) PE greenhouse film;
3) PP onion bags;
4) PE boat shrink wrap;
5) PE bottle redemption bags;
6) PE leaf compost bags;
7) PE fiberglass insulation bags;
8) PP battery case scrap; and,
9) PE pails, e.g. used in fruit, printing, dough operations;
10) PE crates, e.g. chicken, bread, dairy.

We also began testing category 4 materials on a test basis. These materials included:

1) Ontario Bluebox mixed color HDPE bottles;
2) natural HDPE bottles from U.S. suppliers;
3) mixed color curbside bottles from U.S. suppliers;

4) Ontario Bluebox mixed color HDPE bottles and wide mouth tubs; and,
5) post-consumer grocery bags.

Results of These Initial Tests- Collection, Technology and Market Issues

Category 2 Materials

In collecting these materials the biggest issue was identification and separation of materials at the waste generator that we knew had no chance of working from those that did have a chance of working. For example, in some plants we sought PE/PP laminate food packaging film and did not want polyvinyl chloride ("PVC") coated PE films. As visually these materials can be hard to distinguish, we were inadvertently supplied PVC/PE films several times. PVC is thermally unstable to process at temperatures required to process PE and degrades quickly.

We discovered that acrylic-coated PE and PP did not process well, as the acrylic coating burned, turning the PE to an undesirable color. Interestingly, metallized PP film processed well, with the thin aluminum coating (a few angstroms thick) disbursing well. The great problem became marketing the material on account of its silver-blue color. The material was otherwise of high quality. Color would reappear in many instances as an unfortunate roadblock to use of recycled material. Brand-owner marketing departments want recycled material to meet virgin product color capability.

Attempts to recycle paper/plastic laminates like Tang flavor crystal packaging using our extrusion equipment failed. The paper content overwhelmed the melt filtration capabilities of the extruder and started to charr due to the PE melt temperatures required of some 230 degrees Celsius. As a result, we began to evaluate other technologies to use the paper content as a composite filler which ideally could impart improved physical properties to the resin. We did some work with the University of Toronto Chemical Engineering (Dr. Ray Woodhams) and Forestry departments' which had been doing work in this regard. Dr. Woodhams is apparently close to commercializing his process of plastic/wood blends. We anticipate there could be a modest-priced opportunity to move finished product into this application area.

Carpet scrap of interest to us, i.e. carpet made from PP, proved very troublesome to recycle due to the jute backsheet. The PP in the carpet is otherwise a high quality plastic recycle source. Durable objects such as the carpet should be designed with a compatible backsheet.
A similar problem arose attempting to recycle large PP tote sacks which are used in the

thousands by food and chemical companies. The PP material content is quite recyclable; unfortunately, the nylon strapping and handles are totally incompatible.

We found the laminate of PE and PP as generated in disposable diaper manufacture to be a very recyclable material and a very useful material in thicker part injection moulding applications. A barrier to marketing has arisen due to the increasing use of gender-specific colors in the primary product. Markets for white recycled pellets are available, but pink and blue presented problems.

Category 3 Materials

With the startup of the wash plant, we began to experiment with recycling soiled, single resin streams of waste. Our efforts encompassed both film and rigid materials. One overriding lesson learned is that the different waste streams require handling techniques that are often unique to each stream. For example, greenhouse film came in long "greenhouse" length sections. They were exceedingly difficult to handle and feed into the recycling equipment as arrayed.

Agricultural mulch and leaf compost film came in with heavy soil loadings to the point where some form of wash pre-treatment is critical. These preceding materials were quite processable as the film was of a heavy gauge. Unfortunately, the existing process water treatment process could not effectively handle the dirt loadings. The finished product as a result had a high incidence of nucleations from residual dirt. Clearly, when designing the recycling line, one must focus on a limited range of materials and array the equipment to meet the infeed handling and processing demands.

PE bottle redemption bag recycling exposed us to our first thin gauge film challenge. The Phase 1 equipment granulation and drying train provided only very low output processing the high surface area to weight ratio of material needed to be cut and then dried. As well, this material presented the challenge of aluminum contamination in the form of caps and tabs from the cans carried in the bag and not emptied. This material carried through our entire Phase 1 process and was only removed in the extruder melt filters. The problem here was the aluminum formed itself around the backer plates holding the melt filter screens, eventually blocking the entire melt flow. We had to develop an improved separation technology to remove the aluminum before it got to the extruder.

PE fiberglass insulation bags proved quite recyclable, but the trials pointed to the need for enhanced wash and separation capabilities. The fiberglass strands still left in the bag stayed throught the wash process and contributed to a high incidence of melt filterscreen

blocking.

We learned at this time that many makers of the packaging we were trying to recycle were unwilling to work with us to incorporate this material back into their process. We began to change our testing policy- if you do not take it back once we have recycled it, do not bother to send it in. We found our U.S. customers much more willing to work with us than the Canadian companies. For a Canadian-based company, we were very disappointed.

In our grant application proposal to the MOEE, we had expected that PP from auto battery cases would be a staple production item. We had naively assumed that the washed flake coming from the various lead recovery operations would be free of residual lead. To ensure compliance with MOEE regulations, we independently tested flake from a number of battery recyclers. All of the flake we tested proved to be well over the allowable lead content limits. Accordingly, we regretably bowed out of the opportunity to process this material.

Our recycling of pails and crates proved to be only modestly successful. We were plagued by infeed handling issues that bottlenecked our wash plant. As the large market for recycled crate and pail resin has a lower selling price than bottle grade resin, processing rates on this material had to be improved considerably to achieve commercial success.

We realized we had to be much more focussed in the streams of material we sought to run on the equipment. The process was just not flexible enough to handle the range of materials trialed.

Category 4 Materials

By the spring of 1990, Dow Chemical had announced that they and Domtar would not be proceeding with a recycling joint venture. Now, without potentially overwhelming Dow/Domtar competition, Resource began to look earnestly at processing the Bluebox PE bottle materials on a trial basis. A large blow moulder, Plax Inc, also encouraged us to look at processing these materials.

We found the loads of Bluebox mixed plastic we recycled demonstrated significant potential variability in resin composition. As well, the risk was confirmed that some reprocessing questions with respect to hazardous and non-plastic contamination might result if not checked by some prior control.

The Bluebox mixed materials evaluated represented a wide range of plastic products. While most of the non-soft drink bottle portion is HDPE, HDPE materials themselves

exhibited a wide range of physical properties that affected their end-market usability. These variations were pronounced when one considered bottle grades versus injection molding grades, e.g. margarine tubs. The high flow rates required to injection mould thin wall tubs does not permit the blow-moulding of a bottle because the bottle will not hold its shape in the extrusion/blowing process. Removal of aluminum and rubber-type compounds from bottle caps, seals and spray nozzles integral to the bottles emerged as a real problem.

The natural HDPE bottles streams proved readily recyclable. Marketability of these products has been affected by color tinting of the natural PE from colored caps as well as the material's degree of cleanliness and residual odour.

We recognized that with the high number of one litre motor oil and other lubricant bottles in the waste stream some form of improved cleanup of the residual oils was required. The molecular structure of the PE in the bottle is sufficiently porous that hydrocarbons penetrate the subsurface. Jim Horn of Resource proposed a technique used in tertiary oil recovery called supercritical fluid extraction for further investigation. In this process, used bottles are dipped in a liquid carbon dioxide bath; the CO2 is then flashed off leaving the hydrocarbon behind in liquid form which can be removed easily. The flashed CO2 is then recovered by repressurizing the gas to liquid form.CO2 has the ability to penetrate the PE surface and soaks up the hydrocarbons. This process could also be used on hydrocarbon-based pesticide residues in containers. Funding from members of the petrochemical industry was obtained and the University of Waterloo conducted lab scale trials. Apparently, while the process does work, the bath time required for hydrocarbon extraction is long. We do not at this time accept motor oil or pesticide containers for recycling.

Processing grocery sack materials proved to be much more difficult than the films trialed under category 3. The range of non-PE and non-plastic contaminants was significant- PVC, nylon/PE meat wraps to newspapers, clothing, metals, glass, etc. Cutting and drying the thin films used in grocery sacks, now .5 to .7 mils thick emerged as a major processing issue.

In recycling both post-consumer bottles and film, we realized that we had to do much more in terms of enhancing our outsortation of undesirable items prior to washing as well as significantly improving our in-process separation capabilities. This work became the subject of much of our effort in Phase 2, Stage 1. As well, we assisted as a technical reference and supplier of test materials for automatic separation research conducted by the University of Western Ontario ("UWO"). UWO's process used the different electric properties of the

resins (referred to as "triboelectrification") as the sort mechanism. Their research was funded by the MOEE as well as the Canadian plastics industry. The MOEE can provide further information regarding the development status of this research, but at this time we do not believe it is at a commercialization stage.

During Phase 1 of our program, we became an active participant in developing PCR quality criteria. We started to work on developing bale specifications, finished product appearance rating scales and contributed to ASTM committee proceedings regarding recycled materials.

The greatest interest in our Phase 1 activities was from potential customers in the U.S. While we gladly welcomed the business opportunities, it was somewhat frustrating given our Canadian base. Canadian plastic converters, e.g. blow moulders, bagmakers, have been largely inactive. This presumably reflects inaction at the brand owner level whom the converters service, who will not move unless forced by customers, competition or regulation.

By the end of our first year of operations, we had recycled about 1,600 tonnes of material. While the volumes were still modest, the range of materials we had tested was quite broad.

On the plus side in Phase 1, we saw that good opportunities existed to build our bottle and film business on a North American basis provided we met quality and cost criteria demanded by the marketplace. We realized we had to work on improving infeed quality, plus equipment, process and laboratory upgrades. Also, in light of our experience handling and processing materials, and the direction market opportunities were heading (i.e. post consumer bottles and film), we decided to take a much more focussed view to those materials we would process in the Phase 2, Stage 1 project activities.

Phase 2, Stage 1 Project Activities

By the time Phase 2, Stage 1 was underway, Resource had completed negotiating a significant supply-marketing agreement with Dow Canada for PCR from HDPE bottles. Accordingly, most of our Phase 2, Stage 1 efforts focussed on improved recycling of these materials.

Accordingly, Resource approached the MOEE IWDP with an extensive proposal (referred to as "Phase 2, Stage1") to do the following:

A Characterize the Bluebox Materials Collected and Further Assess and Develop Their Marketability

B Investigate Resin Separation Technologies and Make An Assessment of Alternatives

C Improve Existing Recycling Facility Sorting, Separation and Processing Techniques To Dovetail With Mixed Rigid Bottle Collections. Specifically:

a) Develop Upstream Mixed Plastic Handling & Sorting Processes
b) Modify the Existing Recycling Line To Enhance Non PE Plastics and Aluminum Seal Separation
c) Improve Handling and Reprocessing of Cleaned Bluebox Rigid Flake
d) Make Extrusion Additions/Modifications To Better Handle Bluebox Materials
e) Improve Material Testing Facilities

This proposal was accepted by the MOEE under the IWDP and funding support obtained. The following report section describes our Phase 2, Stage 1 activities and findings in the above-noted areas.

A *Characterization of Materials Collected*

As previously noted, the loads of Bluebox mixed plastic we have recycled have demonstrated significant potential variability in resin composition. As well, the risk was confirmed that some reprocessing questions with respect to hazardous and non-plastic contamination might result if not checked by some prior control.

Also, quantification and assessment of the impact of PP and other mixtures on Bluebox HDPE blends and end-market usefulness was performed by Resource and Dow.

Conclusions:

1. Development of a comprehensive, understandable, FAIR bale specification to serve as guidance to our municipal suppliers was essential. We developed this specification based on our experiences.

   Potentially hazardous materials were highlighted for exclusion, plus reasonable limits on non-HDPE plastic and non-plastic contamination were described. Also, freight terms, sampling, rejection procedures and explanatory notes have been included. The specification has been well received by operators.

2. Dow and Resource testing indicated that simple inclusion of tub material with bottle material would not produce a usable product for bottle moulding purposes. The material created was too flexible, resulting in poor top-load strength. Inclusion of small amounts of tub material was acceptable (2-3%), but certainly not at the proportions found in the Bluebox based on our tests, i.e. over 10%.

3. Inclusion of small amounts of specific multilayer bottle material, notably the Heinz opaque bottle, a laminate of PP and EVA did not present a problem at the levels found in the loads evaluated.

4. Infeed raw materials, supplied to our bale specification, produce a high quality product with properties demonstrably close to virgin material. The reuse potential is only affected by food contact issues and the brand-owner marketing issue of complete color consistency. Detailed information with respect to our bale specifications is available upon request.

B *Resin Separation Technologies- Assessment of Alternatives*

Sorting techniques are slowly developing, but many aspects are still rudimentary. The industry must develop high-speed separation techniques to separate incompatible plastics.

We examined a number of technologies from older technologies such as hand-sorting, the float-sink system using water that our Phase 1 system employed, or a series of float-sink systems using solvents of various densities. Newer technologies that we tested or reviewed were; hydrocyclones, fluidized beds, star wheels, friction belting, trommels, walking tables, electronic sensing (chlorine detection), optical sensors, electrostatic separation, as well as combinations of the preceding.

Findings:

1. Hand-Sorting

This method is extremely labor-intensive and prone to error. We calculated time-motion analysis in a properly designed sort environment. Our findings with respect to capabilities and costs indicate a variable sorting cost of 1.5 to 7 cents per pound, depending on the sortation required as a function of the range of materials collected and their intended end markets.

2. Float-Sink

We found that this approach is not 100% effective in separating incompatible polymers. Chief problems include wetting characteristics, air retention, specific gravity range cross-over, plus filler and pigmentation induced specific gravity modification.

3. Solvent-Based Systems

While this Dow Chemical-patented process permits much more precise specific gravity separation, problems with solvent cleaning/disposal, plasticizer effects and excessive costs were evident.

4. Hydrocyclones

This enhanced gravity separation technology, borrowed from the mining industry has proven itself useful in effecting a basic separation of polyolefins (PE & PP) from other incompatible, heavier than water polymers. It utterly fails to assist in sorting these heavier polymers (e.g. PET soda bottle flake, PVC shampoo bottle flake). Resource retrofitted these units in our line and got immediate product improvement over the previous float-sink approach. A recurring problem does exist with respect to uneven particle size distribution, which can affect the separation capabilities of this system.

5. Fluidized Beds

Only basic inquiry was done regarding this method. It would be of some usefulness as an alternative to separating the polyoefinic fraction, but again the problem of separating of heavier incompatible polymers exists.

6. Star Wheels

This mechanical separation approach is ideally suited for separating very high melt flow tub lid material from the stream. In addition, it is quite good at separating glass, dirt and other fines from the sort stream. The system is also self-cleaning and quite flexible in sort sizing modification.

7. Friction Belting

This approach uses the surface friction variation among polymers to effect separation. By tilting a specially designed rubber belt, plastic materials will either climb the belt or slide back down. Only preliminary research and experimentation has been done by Resource to date.

8. Trommels

We found that while these devices are in widespread use in various material recovery facilities, they are not a method of choice for handling rigid plastic materials because of material hangup in the trommel. Unfortunately, the trommel is not self-cleaning and the hung material can be hard to remove.

9. Walking Tables

We reviewed the walking table technology employed at the Waste Management Inc. facility in Etobicoke. We think there could be potential for limited application of this technology in plastics sorting, but we lean to the friction belting/tilt table approach.

10. Electronic Sensing Techniques

a) X-ray backscatter

This method is used to detect chlorine content, thereby detecting PVC bottles. This detection technology is performing well; the greatest difficulties are "singulation", i.e. arranging and passing one bottle at a time and the air ejection system which sometimes misfires.

b) Optical Sensors

Spectroscopic and/or refractive index techniques and infrared sensors are utilized. The differing opacity and reflective properties of different polymers are calibrated and a microchip is programmed to air eject materials based upon the perceived material. Problems are still being encountered with the apparatus to line containers up single file in preparation for the sensor phase.

11. Electrostatic Separation

As noted earlier, the University of Western Ontario has been working on this project with funding assistance from the MOEE. While early results were encouraging, we have not seen any recent reports of further progress.

C *Develop Existing Recycling Facility Sorting & Separation Techniques To Dovetail With Mixed Rigid Container Collections*

a) Develop Upstream Mixed Plastic Handling & Sorting Processes

Resource proceeded in October 1992 to enhance it's ability to sort mixed curbside feeds in order to maximize value for the loads received. We designed and had fabricated our own custom sort line. The line is about 70 feet long, 15 feet wide and

12 feet high. Our primary focus will be on recovering value for PET inclusions and to separate natural from mixed color bottles.

b) *Modify the Existing Recycling Line To Enhance Non PE Plastics and Aluminum Seal Separation*

We modified the Phase 1 wash line by installing a wash tank, hydrocyclone separators and much improved mechanical driers. The results proved to be a success, with finished product cleanliness, purity and dryness vastly improved. As well, our downtime experience with these new components, after correcting a fabrication flaw in one of the driers, has been excellent.

We still have a minor problem with residual aluminum from bottle seal tops as found in some household cleanser bottles. We can capture this contamination in our melt filters; however, we had to redesign our screen backing plates to minimize the effect of these materials.

c) *Improve Handling and Reprocessing of Cleaned Bluebox Rigid Flake*

We had severe difficulties dealing with the volumes of clean flake coming off the end of the recycling line. It was imperative that we attach buffer/feed silos' to the end of the recycling line to buffer throughput and feed the extruders flake automatically. The silos we have installed use special piping, anti-bridging devices and automatic level controls. Minor problems with level controls and anti-bridging motors have been largely worked out.

d) *Extrusion Additions/Modifications To Better Handle Bluebox Materials*

The large EREMA extruder that we acquired has worked quite well. We modified it in many ways to improve its performance. For example, we redesigned the screw to achieve a better balance between mixing and back pressure. Also, we doubled up on the vaccum-venting system to draw off print inks. We added special sections in the feed zone to increase kinetic activity to get increased heat that enabled higher moisture level tolerance and higher throughput.

To better understand our operation, we have included a plant layout schematic and more detailed process description attached as Appendix A.

e) *Improve Material Testing Facilities*

Our lab now offers a good basic level of capability. We have sophisticated moisture analysis equipment, binocular hot-stage microscope, load frame with computer analysis, statistical quality control software, test film tower, ASTM injection moulding machine, fume hood, explosion-proof oven, compression moulder, falling dart impact tester, and of course melt flow and density measurement equipment. We are now in a position where we can supply our most sophisticated customers with all the basic test data they need.

By the latter stages of the Phase 2, Stage 1 program, we were finally at a point where we could reliably produce on-specification HDPE bottle PCR product consistently. At the same time, PCR users were starting to emerge. Drain tile and agricultural pipe makers started to consume increasing quantities of our material. Early leaders using recycled plastic back into bottles were the motor oil suppliers, particularly Shell Canada, who now incorporate a 50% level of recycled content in their one litre bottles. Also, Procter & Gamble's efforts were stimulating household chemical competitors to begin to use recycled content in their bottles.

We have also successfully developed a tire rubber crumb/recycled plastic compound that has been used to manufacture backyard organic composters. The key technology here is the additive used to create a hydrogen bond between the tire and plastic materials.

For year two, the total weight of plastic recycled exceeded 3,000 tonnes. Year three processing was in the range of 6,000 tonnes.This was a substantial improvement over years' one and two, but further progress in our volume capability with the modifications to the Phase 1 equipment in Phase 2, Stage 1 is achieveable.

Also by this time, Ontario had become one of the leading recycling jurisdictions in the world with the Bluebox residential curbside recyclable waste collection program. Plastic waste, mainly bottles, was now being collected in an increasing number of Ontario Bluebox municipal programs. Bluebox program statistics indicate that the average Ontario household produces in excess of 33 pounds of rigid (i.e. non-film) plastic waste per year. Based on the latest data available generated from the program, the current anticipated annual collection rate of rigid waste plastic material through Ontario's Bluebox program is estimated at about 50% of the plastic consumed, i.e. 16.5 pounds per household.

When the participation results are extrapolated over total industry resin consumption statistics, the potential rigid and film recycling volumes are truly staggering. As Ontario now has in excess of 3 million Blueboxes in circulation, this collection mechanism translates into rigid plastic material alone available for recycling of more than 50 million pounds per year, if all municpalities participated. All municipalities collect the PET soda bottles, while currently just under 2 million blueboxes in Ontario collect other plastics, principally HDPE bottles. The geographic scope of collections, while predominantly in southern Ontario, extends from Cornwall in the east to Sarnia in the southwest.

Recommendations & Conclusions

Collection Cost Uncertainty

Despite the Ontario Ministry of Environment and Energy 1992 municipal landfill diversion target of 25%, despite the enhanced financial resources and declared objective of Ontario Multi Materials Recycling Inc. Phase 2 ("OMMRI2") to expand Bluebox mixed plastic collections and despite municipal garbage dumps daily being fed a diet of very recyclable plastics comprising at least 18% of waste measured by volume, a number of municipalities have been reluctant to expand plastic collections beyond PET beverage bottles.

Why this reluctance? Initially, because municipalities saw the cost of diverting plastics from landfill far exceeding the value of the recyclable plastic materials. This concern was largely dispelled by the joint EPIC/MOEE Collection Cost Model Project completed in the summer of 1992 (Barry Wood, President of Resource Plastics was the Chairperson of this Project), which demonstrated that the incremental plastic collection costs were reasonable ($190/tonne) in relation to: a) the total costs of regular garbage collection avoided ($50/tonne); plus, b) landfill consumption avoided ($50/tonne); plus, c) revenue earned from the plastic recyclables ($75/tonne). As one can see, even in a time of cyclical low prices for PE, HDPE bottle collection can be nearly a breakeven proposition.

Markets... Consistent, High-Value End-Markets

To bring the just-stated economics into equilibrium or profit for municipalities, it is important that plastic recyclables be consumed in the highest value-added markets available in order to maximize revenue potential and offset costs for all participants in the chain- from municipalities to the recycler. If Bluebox plastic recyclables are consumed in plastic lumber applications, the municipalities' cost concerns would be borne out, as the real value in the plastic would never be realized via this application. As a result, the municipalities would

never receive a reasonable amount to off-set costs of their Bluebox plastic collection efforts, and plastic collections would have to be continually subsidized at the Bluebox collection end or plastic lumber sales end. As events unfolded, plastic lumber operations have failed and several municipalities became caught up in broad plastic collection programs in conjunction with these failed concerns. This has left the municipalities trying to market a mix of plastics that were very difficult to sort and utilize economically by processors such as Resource.

Municipal Plastic Collections- A Multitude of Material Collection Definitions

Another problem that has emerged with the evolution of plastic inclusions in the Bluebox is that there is little consistency among municipalities regarding the definition of which plastics will be collected. As noted above, plastic lumber operations contributed to the problems in this regard by going to municipalities with a broad collection specification that put the collection program ambitions well ahead of plastic recycling technology's current ability to process it.

The problem of wide variability in collection definitions used by Ontario municipalities needs to be addressed forthwith. We would propose a step by step approach; first, agree on a defined range of materials for collection now, within the economic capabilities of current collection, sorting and recycling technology; 2) concurrently, agree on a program of experimental development in sortation/recycling with time targets. Limit expanded plastic collections to those municipalities already doing so and use these areas collections to test new required sorting technologies; and, 3) expand municipal collections to this broad specification as technology permits. With this program, there should be a regulation enforcing sponsorship of the development of sortation/recycling technology. This could be funded via a regulatory incentive for pursuit of waste reduction, reuse and/or recycling initiatives, e.g. advance disposal fees, which are refundable based on achievement of reduction, reuse and/or recycling targets.

The Need For A Plastics Sortation Facility

As a member of the Canadian Society of the Plastics Industry and an active participant in SPI environmental affairs, Resource has been a long time supporter of the need to have a buffer organization between the post-consumer plastic recyclers and the municipal suppliers. This buffer, referred to by many as SORTCO, is needed to provide municipalities with an assured market for plastic recyclables while not forcing the difficult task of resin sortation onto the many municipalities who have neither the sophistication nor economies of scale to successfully sort the plastics in order to market them. On the buying side, Ontario post-consumer plastic recyclers need better quality raw materials to survive.

In Resource Plastics view, the advantages of establishing a sortation facility vastly outweighs the disadvantages. If such a facility is not put in place, at least for say a five year transitional basis, the full range of post-consumer plastic packaging materials may be collected in Ontario but they may NOT be suitably recycled.

The imposition by government of punitive legislation seriously affecting the plastic packaging sector is quite possible. The industry must act promptly and effectively to positively shape possible government actions. We know a number of major participants in the Canadian plastics industry are similarly concerned and see a need for a sortation facility on a transitional basis until the plastic recycling industry and post-consumer plastic recycling technologies mature.

With the preceding concerns in mind and expressions of interest from some in the industry, we proceeded to prepare a proposal to establish and operate a post-consumer plastic packaging materials sortation center on behalf of interested major participants in the Canadian plastics packaging industry. The goal was to collect and more effectively sort for high-value recycling a broader range of plastic materials. We needed to obtain a commitment from the industry that they would take stewardship for the sorted and/or recycled material by buying the sorted raw material or finished pellets/flake for resale to cover the costs of operating the sort facility.

Following our presentation, numerous meetings and discussions ensued. The industry progressed to a point where an industry organization was incorporated (the "CSPI") to move the project forward. While certain members of the industry were prepared to fund this corporation and move forward with a wholly-owned Resource subsidiary called MERIT Plastic Recycling Canada Inc. to develop a program of broad, sophisticated plastics sortation, not all major players would agree to join the coalition. The project has ground to a halt. It is simply impossible for Resource alone to go further without industry participation and stewardship support.

Some DO's and DON'Ts For Prospective Plastic Recyclers

1) DO have lots of equity funding in place before starting.
   We started our Phase 1 operation thinking it was well capitalized. On paper it was. The lesson we learned was that always budget for substantially higher capital and operating costs than hoped for. We had to inject a further $2 million of equity capital above the startup $1.5 million just to get started on Phase2, Stage 1 activities. Plastic recycling is not a business for players that cannot raise sufficient capital to achieve production economies of scale of around 20 million kilograms per year. At the same time, the recycler must produce top notch product, so buying the best equipment is critical. Resource now has over $6 million in share capital plus over $2 million in MOEE grant assistance.

2) *DO have a full complement of engineering staff, from production to maintenance to materials to process.*

We started off with only chemical engineering expertise. We now have on staff mechanical, process and metalurgy engineering staff. A range of professional experience and expertise is critical in this new industry. As well, we have three full-time millwrights and a journeyman electrician on staff.

3) *DO recognize that the business cannot be built on the expectation of legislation alone.*

When considering the expected marketplace, do not build financial forecasts on the premise that product prices will be boosted by mandating legislation. Assume that product will sell for no more than say 75% of virgin prices- if that!

4) *DO expect significant U.S. competition acquiring raw materials and in selling finished product.*

The marketplace and competition for procuring raw materials and selling finished product is North America. The quality standard that will be required to compete will be at the ISO 9002 level.

5) *DO NOT embark in the plastic recycling industry without immediately having economies of scale, e.g. 20 million plus kilograms/year capacity UNLESS you have a niche market.*

Prices are extremely competitive. Recyclers are competing in a marketplace dominated by huge virgin resin companies with substantial economies of scale.

6) *DO NOT start before having a sound financial plan and skilled financial professionals on board.*

Monitoring the startup of a new company in a new industry requires tight and constant monitoring of the operation, costing of activities and control of expenditures.

7) *DO NOT trust the expertise of equipment suppliers who claim to have the answers, e.g. there is no such thing as a turn key plastic recycling system.*

We learned the hard way that the only way recycling expertise is acquired is by doing

recycling. While many equipment makers may claim they have special insight, nearly all established recyclers design, engineer and build their own custom-designed wash recycling lines. These lines are designed to handle the process issues specific to the products the recycler deals in.

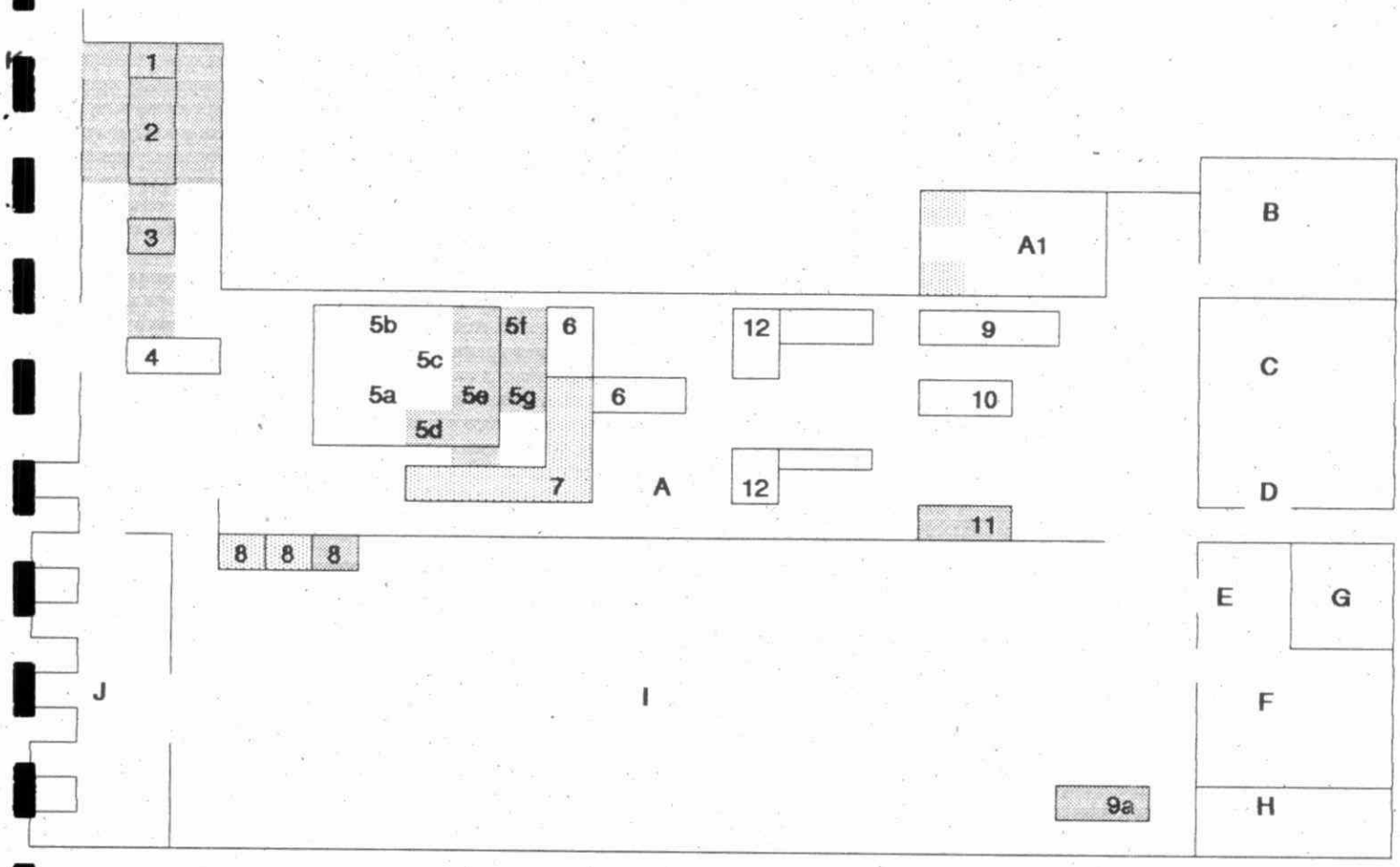
A Final Word

Resource is now one of the leading plastic recycling companies in North America. We are constantly working on improving our processes, capabilities and product quality while reducing costs.

APPENDIX A

Plant Layout

Brantford Facility Plant & Process Overview– Phase 2, Stage 1 Facility



Total Area 40,000 sq. ft.

Legend

Area In Process of Being Modified

Area Recently Modified

Numerals– Plant Equipment

(Material Flow Follows Number Sequence)

1 Bale–breaker (bottles only)
2 Sort Line– custom designed/built
3 Guillotine cutter (film only)
4 Herbold Shredder– initial size reduction
5 Herbold Wash Line: 5a Pre–wash removes dirt, stray metal 5b Wet granulator flaking, cleaning 5c Dewatering augers 5d Second wash, slurry for Hydrocyclones (5e) to purify polyolefin stream via intensified density separation 5f Multi–stage, self–cleaning mechanical driers 5g Thermal driers
6 Flake silo storage/feeding for EREMA 160E
7 EREMA 160E– 160mm dual–vacuum vented, modified extruder
8 Rigid Flake Storage Silos
9 6 inch compounding extruder 9a Compounding blenders
10 4.5 inch compounding extruder
11 Post–pelletizing blender
12 EREMA 80 extruders

Alphabetic– Plant Space Utilization

A Production Area
A1 Production Lab
B Office
C Equipment Storage
D Maintenance Parts and Tools
E Womens' Lockers/washrooms
F Mens' Lockers/washrooms
G Plant Manager, Material Coordinator, Maintenance supervisor office
H Pigment Room
I Inventory Storage
J Shipping/Receiving
K Outside Storage

Process Overview

Initial Sorting

Bottle material, in baled form, is currently brought into the facility via the drive-in door near #4, where the bale is manually broken and sorted on a 35 ft conveyor. Here stray metal, glass, paper, PET and the expected PVC is manually removed. This area has been totally revamped by the addition of more sort space, a bale-breaker and custom-designed sorting line to mechanize some sortation tasks as well as streamlining to increase flows and move the non-processed materials off into balers for value recovery.

Film materials are currently loaded into the guillotine cutter (#3) for pre-cutting and delivery to the shredder. We are looking to move the cutter out-of-line as we now see that our grocery bag customer bales do not need precutting.

Size Reduction, Washing and Drying

Both bottle and film materials are fed by conveyor into the Herbold shredder where they are size-reduced to hand-sized pieces. These pieces are conveyed into the pre-wash tank (#5a) where heavy contaminants are removed. The largely polyolefin material, which floats in the pre-wash water is then paddle-fed into the large wet granulator. Here, the material is reduced to about 1/2 inch square pieces. There is a tremendous slurry cleaning action created here as the water-drenched materials rub during granulation.

The particle size permitted to continue is tightly controlled by pass-through screens in the granulator. The material is fed into high-speed, mesh-wrapped dewatering augers, which are mounted on an incline. These augers do the initial water removal as well as pulping out of bottle paper labels. The removal of water and non-plastic contamination is vital to successful extrusion and repelletizing.

The major Phase 2, Stage 1 retrofit involves the next phase. The material is now fed as a slurry to a new second cleaning wash and the material is then fed into hydrocyclone separators. The hydrocyclone technology, long-used in mining, work by creating a vortex which emphasizes the specific density variation between the light polyolefin fraction and the heavy PET/PVC/other contaminants fraction. The hydrocyclones pass water-entrained polyolefins out the top, while removing remaining heavy contaminants out the bottom.

Next, the pure polyolefin stream will again be auger-dewatered and then passed to new multi-stage mechanical driers, which centrifugally spin-off most remaining water. Lastly, the material is passed to modified thermal driers where moisture levels are reduced to a level which extruders can consistently handle with no downgrading of output pellet quality.

Extrusion/Compounding

Film flake material is airveyed into storage/feed silos for automatic loading onto the EREMA 160E extruder's feed conveyor. This extruder was specially modified in the factory in several modest but useful ways to improve its performance pelletizing our film products. Clean rigid bottle flake is airveyed to storage silos (#8) for airveying to the 6 inch compounding line for direct pelletization or fed to the compounding blender (#9a) for custom coloring prior to pelletization. As well, Resource has a growing compounding business that involves recycled material that has been purchased from third parties.

The 2 EREMA 80's (#12), smaller unvented extruders like the EREMA 160, are used to directly process clean film laminates such as diaper scrap and metalized polypropylene.

Finished materials are stored on and off-site in 500 kilogram boxes ("gaylords"). Resource is installing bulk pellet storage and loading facilities.

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